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Reconstruction of Schools in Saint-Petersburg: Renovation Highlights

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Abstract

An optimal network of state educational institutions has been developed in Saint-Petersburg. It has been streamlined over the last years, and now it can be represented as unique public instructional environment which makes it possible for children of any educational institution to elicit their creative potential.

The article deals with a brief analysis related to forecast of general education development in Saint-Petersburg. Modernization of educational institutions and school facilities is considered in the context of the architectural typology and city planning, and energy efficiency.

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Keywords: General education, primary education, educational institutions, reconstruction, energy efficiency, school.

1. Introduction

The education system of Saint-Petersburg is a developed network of primary, secondary (comprehensive) and high educational institutions, and it can be featured by a wide range of educational services and ease of reach against the background of a big city [1].

There are 696 educational institutions performing educational programs at public primary, secondary (comprehensive) and high schools in Saint-Petersburg, where over 370 thousand children are taught (dated to 2012).

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The network of state educational institutions in Saint-Petersburg is represented by the ones of different types, and this makes it possible to completely meet individual and families' demand for any type of high-quality educational service. Schools operate as a social disciplinary education center in living environment. Schools are open to public and call for active communication between society and a family as well as for bringing up children [1, 2].

The experience of teachers from Saint-Petersburg is spread out through the annual conferences and workshops held as at local as at national and international level. The Saint-Petersburg Educational Forum, which takes place every spring and hosts over 5 000 participants from more than 60 regions of the Russian Federation and other 15 countries is the most significant event for education system development.

Taking into account the demographic forecast data for the period up to 2020, according to which a number of students is going to rise considerably (by about 50%) [2], and a perspective target to increase a number of school years up to 12, a drastic redesign leading to increase in room area is required for the purpose of reconstruct existing schools in the majority of cases [3].

However, design projects for reconstruction of certain school buildings directly depend on complex modernization of the whole educational institution network, which is currently performed in Saint-Petersburg. Major provisions for modernization have been stated in the Development Strategy for education system of Saint-Petersburg in 2011–2020 «Petersburg school 2020» [2]. In particular, it is referred to a possible change in the area of expertise of existing schools, increase (or decrease) of occupancy rates, functional structure change, rooms classification, usable area increase by adding extensions assigned for gyms and swimming pools.

Therefore, reconstruction of certain school buildings are naturally interconnected with a versatile on-going modernization process assigned for the whole network of educational institutions in Saint-Petersburg.

2. Literature review

A plenty of researches carried out in different time by Dvorkina E.B., Zherdyev V.I., Slavina T.A., Smirnov V.V., Ezhov V.I, Platonov G.D. and others, are focused on typology and architecture of school facilities.

A research and scientific article «Architectural and planning methods for reconstruction and modernization of existing schools of Leningrad», worked out in the Leningrad State University of Architecture and Civil Engineering (LSUACE) in 80s in the 20th century by Zudin A.V., deals with a comprehensive analysis of exciting school buildings in Saint-Petersburg and main trends in reconstruction and modernization design methods assigned for new school buildings.

Mironyuk A.V. performed his thesis research 'Architectural planning methods for reconstruction and modernization of existing school buildings in large cities (researches and recommendations basedon the case study of the city of Ukhta) at SPbSUACE Saint-Petersburg State University of Architecture and Civil Engineering in 2005. This article is focused on methodologies and recommendations on development and optimization of the system and types in regard to general education schools in large cities.

City planning issue in terms of school buildings design is elicited in the works of Poluy B.M., Smirnow V.I., Stepanov V.I. and others. Pedagogical, hygienic and social factors in regard to school design are stated in the works performed by Antropova M.V., Rittelmaier K., Serdyukovskaya G.N., Korniyevskaya E.I., Kovalyova G.A., Panyulova Y.G, Sokolenko G.A., Levin V.A. and many others.

3. Types of educational institutions

Nowadays, there are the following types of educational institutions:

- Primary school (duration of education is about 3-4 years);
- General education school. It is established as a separate general education institution from the year 1 to the year 9 including, it can be also a part of a secondary (comprehensive) education school;
- Secondary (comprehensive) school. It can be established as a separate school of a 3rd stage as well as it can have schools of the 1st and 2nd stage as its parts (duration of education is about 2(3) years or 11 years)

Therefore 3 stages of general education school can be identified:

- I stage – primary general education (1-4 years);
- II stage – compulsory general education (5-9 years);
- III stage – secondary (comprehensive) general education (10-11 or 8, 9, 10, 11 years) [5]

General education school-laboratory. It is a general education school that performs general secondary educational programs and experimental programs. Experimental educational programs can ensure the establishment to work in innovative learning environment at a high level. These programs are developed and performed with participation of staff researchers working in laboratories. School-laboratories have 3 education stages.

High profession-oriented schools deliver education to students of 8-11, 9-11 or 10-11 years amounting to a number of 20 per 1 group. It can be a multi-purpose and one-purpose high school.

Gymnasium is a general education institution performing regular educational programs of a secondary (comprehensive) school, and as a rule, it as an institution with a specific area of expertise, primarily in humanities, with in-depth learning of 2 or 3 foreign languages. Gymnasiums can have only 2nd and 3rd stages of education. Duration of education is about 7(8) years.

Lyceum is a general education institution performing regular educational programs of a secondary (comprehensive) school with in-depth learning of a variety subject areas and professional retraining ensuring on-going education and smooth shift from secondary education to higher one. It is primarily established as an institution of the 3rd stage, and it also can start from 8-9 year. Duration of education is about 2(3) or 4(5) years.

Evening (shift-type) general education school. It is established as a separate institution of the 2nd and 3rd stages or only of the 3rd stage [4]. Network of general educational institutions in Saint-Petersburg is shown in Fig. 1.

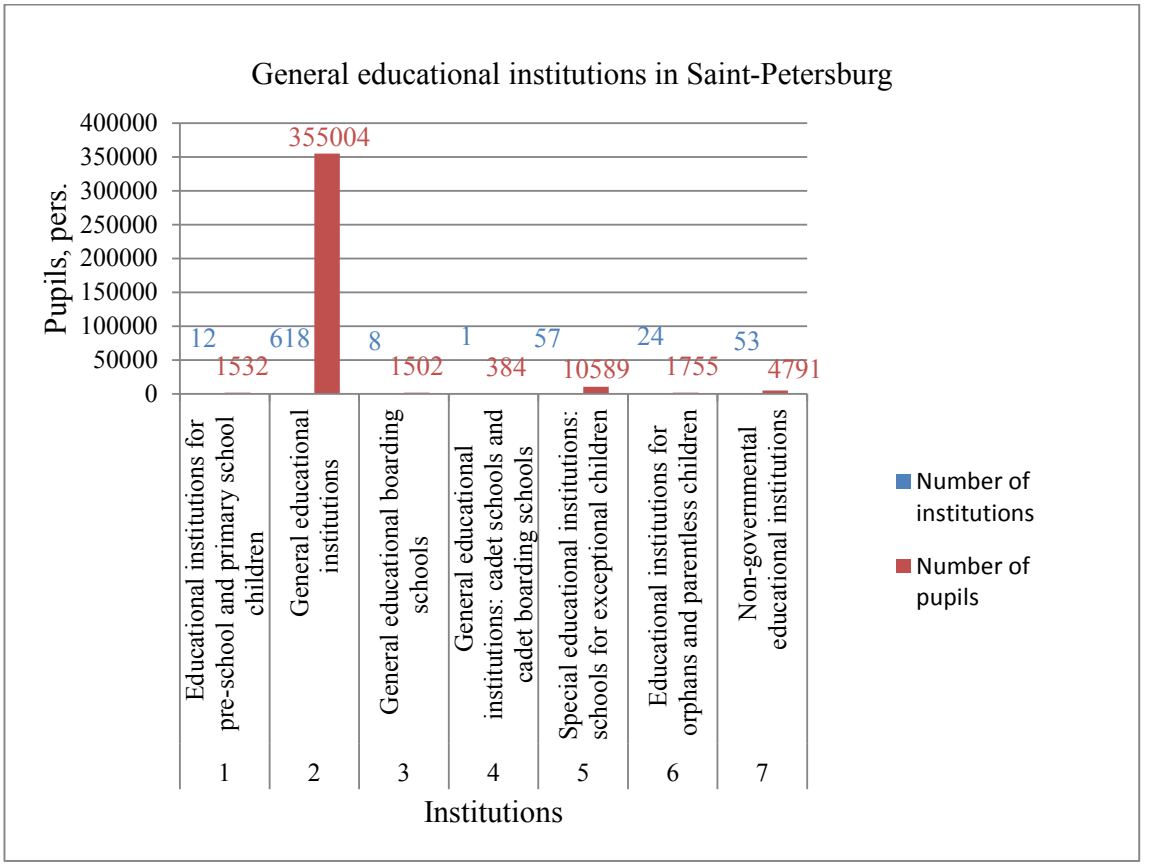


Fig. 1. Network of general educational institutions in Saint-Petersburg

4. General education system modernization in Saint-Petersburg

The general education system model ensuring high-quality education is currently performed under the state program 'Strategies for education system development in Saint-Petersburg in 2011–2020. Saint-Petersburg School 2020'. [2] The strategy is based on the principles of the governmental policy of the Russian Federation in the field of strategic planning for education.

The Strategic Mission of Saint-Petersburg School is stated as overall equal availability of high-quality education for different and equal citizens of Saint-Petersburg.

There are four major targets.

To ensure equal conditions for education and upbringing for all children and young people living in Saint-Petersburg having different opportunities background.

To ensure on-going professional development of a contemporary teacher.

To form 'Open public school'.

This issue is targeted at creating new intensive educational environment to pursue social and educational partnerships, cooperation with business, interaction with science, art and politics, and other forms of public participation in education management.

Efficient and independent school formation.

to manage a School efficiently;

to support innovative pedagogical practices in terms of having solid resources for long-term education system development and as an evidence of social impact on educational activities [1]

Major forecast indicators related to education system development in Saint-Petersburg have been worked out based on data obtained when monitoring performance indicators of executive authorities and living standards of Saint-Petersburg valid for 2010. (Tab. 1)

Table 1. Challenges to be achieved in terms of general education system development until 2020 [2]

№ i/n	Indicator name	Measurement unit	year		
			2009	2012	2020
General and supplementary education					
1	Ratio: Average monthly nominal wage of teachers and educators working in state educational institutions (hereinafter SEI) to Average monthly nominal wage of employees engaged in economy of Saint-Petersburg	%	65.83	74.5	98.0
2	Number of vacancies in pre-school state educational institutions per 100 children under school age	vacancies	67.1	73.0	85.0
3	Number of people satisfied by the quality of general education	%	68.6	73.0	85.0
4	Percentage of the children who passed Unified State Exam in Russian Language taken from the total number of the children who participated in this exam	%	97.9	97.5	98.5
5	Percentage of the children who passed Unified State Exam in Mathematics taken from the total number of the children who participated in this exam	%	97.5	96.5	98.0
6	Percentage of SEI equipped to meet the requirements for disabled people willing to attend institutions	%	51.0	60.0	80.0
7	Percentage of full-time SEI being in disrepair or the ones that need major repairing taken from the total number of full-time SEI	%	12.5	1.5	0
8	Percentage of the children listed in health groups '1' and '2' taken from the total number of pupils studying in SEI	%	77.0	76.5	80.0
9	Percentage of the teachers who have working experience up to 5 years taken from the total number of the teachers working in SEI	%	8.53	12.0	16.0

Note: Reconstruction design projects for certain school buildings are closely correlated with complex modernization of the whole network of educational institutions of a district.

5. General education system modernization in Saint-Petersburg

When developing reconstruction design project for a network of educational institutions of a district the following should be considered:

- Actual demand for vacancies in educational institutions and vacancies supply for children not only from this district but also from the city (e.g. gymnasiums, colleges);
- Number of vacancies in educational institutions under a planned reconstruction project assigned for a certain district based in estimated number of district citizens.
- Periodical oversupply of pupils and idle vacancies in schools and nursery schools caused by social, demographic and economic factors. With the aim to compensate these misbalances it is suggested to develop comprehensive design projects (for varied use) for educational institutions able to supply a required number of vacancies in schools and nursery schools depending on the demand.
- Possible needs to use existing school buildings for the purpose of a new type of a educational institution development, f.e. gymnasiums and colleges, and in case of nursery schools there can be new pre-schools and schools, f.e. pro-gymnasiums and educational institutions for pre-school or primary school children "primary school – nursery school".
- Deficiency of areas in the districts under reconstruction when it comes to construction on new schools. Due to this reason it is rational to develop reconstruction design projects with the maximum capacity by adding extensions.
- Vacancies capacity of schools under reconstruction depends on the type of school building. An optimal capacity for the largest schools to be reconstructed is 33 classes. About 25 or 30 pupils can be enrolled in one class. An optimal capacity for pre-schools to be reconstructed is 10 groups/200 vacansies/, or 10 cells /200 vacancies/ when redesigning a pre-school into the of assigned for varied use [3].

Reconstruction design projects for certain school buildings are closely correlated with complex modernization of the whole network of educational institutions of a district.

5.1. Architecture and typology factor

General requirements for school design include the following:

- area-use planning – general public area and area for studies;
- rooms for studies are to be divided in terms of age and subjects (a set of rooms for primary school (I stage), a set of rooms for pupils of 5-8(9) years of studies (II stage), a set of rooms for pupils of (9)10-11 years of studies (III stage according to area of expertise), a set of rooms for natural sciences, a set of rooms for laboratories and workshops, academic and information center – library).
- convenient horizontal connections between main rooms for studies and academic and information center;
- "flexible" arrangement of space for studies based on enlarged structural unit;
- leisure center creation, combining rooms for forums, gyms, audience halls, canteens, administration;
- independent operation of all the room blocks of the whole school;
- natural interconnection of rooms for studies with rooms for training and practice and recreational land area of a school;
- interesting architecture of a school based on the synthesis of contemporary pedagogical methods and architectural image of a building.

As a rule, when reconstructing schools, it is necessary to redesign school with the purpose to increase area of classrooms (increase in number of laboratories should not exceed the number of classrooms). It is also necessary to consider prospective governmental plans for smooth transition to to 12-years education with the change in

organizational and academic structure of a school for the capacity of 33 classes, i.e. to change the scheme 3-3-3 into the 3-3-2 one with a reduced number of classes in a high school [3].

In case of 5-storey schools it is impossible to add another floor, and with the aim to increase capacity of the building extensions are suggested. It is required to design the 5th storey for rooms to be rarely used (if any) in the 5-storey schools under reconstruction [6]. In the case of 2 or 3-storey schools it is possible to add extra floors up to the height of 4-storey building in accordance with its engineering status. It is also possible to increase capacity due to extra extensions. It is recommended to host primary school rooms or rooms of general use in extensions.

An extension to host primary school added to an existing school building should have a direct access to the building of general use. The extension for primary school can be connected with the main building under construction using only first floor. School rooms of general use must be directly connected with the main building.

As a rule, when reconstructing buildings with rigid structure of bearing walls there is a need to increase area of certain rooms and their total area because design and planning solutions must be adjusted to structural scheme. There is limit for specific total area of 11 m2 per 1 pupil (the limit value was stated for the city of Moscow in the Attachment № 1 to MCCS 4.06-96) to avoid significant excessive use of space [4]. Rates for structure and area of rooms in schools under construction have been also specified, rates for area per 1 pupil: in gyms - 06-07 m2, in recreational areas - 1.6 m2, in audience halls – 0.8 m2, in canteens – 0.7 m2 [4].

Let's take a reconstructed secondary comprehensive school № 653 in Kalininskiy district in Saint-Petersburg as an example (Fig. 2). This secondary school was open in 1957 and reconstructed in 2009. After reconstruction the school appeared to be a unified multi-purpose educational centre: the building hosts the secondary school with the capacity of 400 pupils and pre-school educational institution (PEI) for 80 vacancies. The building has an extension assigned for a standard gym. A sport area with a swimming pool, a football pitch, race tracks and an integrated football and basketball court in the northern part of the territory [7].

Fig. 2. School № 653, before and after reconstruction, Saint-Petersburg, Mechnikov pr. 5

5.2. City-planning factor

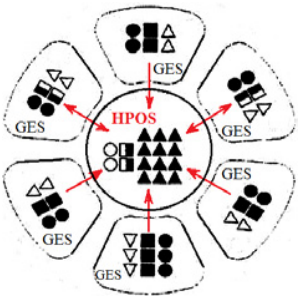
Transition from unified comprehensive school to the three-stage general education system can make t complicated to form a network of buildings in the city environment. It also determines a variety of types according to purpose of use (function), organizational and academic structure, number of classrooms. In particular, introduction of «High Profession-oriented Schools» into district development may produce a significant impact on city-planning.

The Federal Education Law assumes differential education in accordance with areas of expertise for high school pupils (8 - 11 years). With the aim to sort it out the Moscow's program «Education in the capital city-3» implies establishing specific high profession-oriented schools (hereinafter HPOS). A high profession-oriented school is a network one, i.e. assigned for high school classes of the surrounding comprehensive schools. As a rule, there are two types of HPOS:

1) With constant high school classes (8 - 11).

2) With constant classes for pupils who study in 10 - 11 years and for pupils of 8 – 9 years who come to take in-depth classes at a more contemporary school if to compare with a conventional comprehensive school. The major difference of a profession-oriented school from a conventional one is that the first one has the rooms for special profession-oriented use where pupils can practice according to their areas of expertise – social issues and humanities, natural sciences, technical and engineering issues; laboratories and resource centres [8].

Modernization of the existing comprehensive school network of the dwelling district ‘Kon’kovo’ in Moscow is exhibited in the Fig. 3 [8].



primary school (1 - 4 years); secondary school (5 -9 years); high school (10 – 11years); 1 symbol per 1 set of pupils; pupils are transferred to HPOS; pupils attend HPOS several times a week;
GES – General Education School;
HPOS - High Profession-Oriented School;
SH – Social issues and Humanities;
NS – Natural Sciences; T – Technical issues;
S– Sports and Health

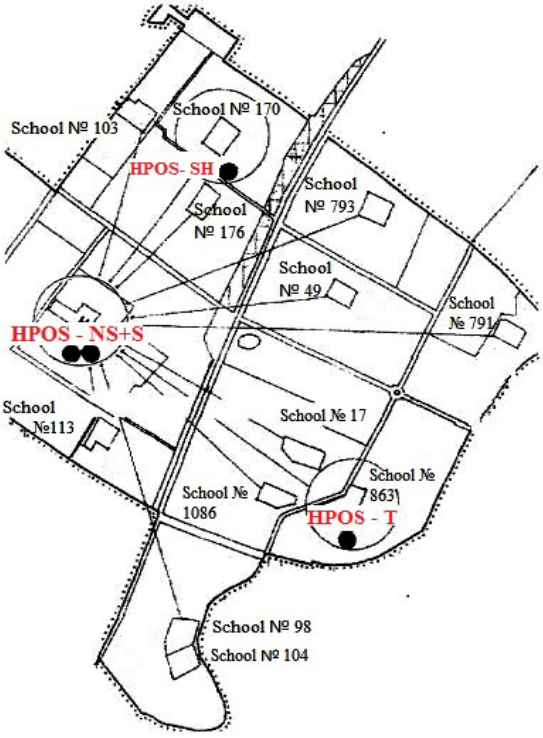


Fig. 3. , a) a principle for a school network arrangement in a dwelling district, b) an offer for modernization of the existing comprehensive school network of the dwelling district ‘Kon’kovo’

5.3. Energy efficiency

Modernization of educational institutions is targeted at ensuring positive dynamics for fuel and energy consumption reduction. Educational institutions under control of Education Committee are located in 2 278 buildings [1]. According to an analysis of technical and engineering status 80% ob buildings have structural members, which need repairing. Since the requirements for energy consumption have been tightened practically all the existing schools have low energy efficiency class and need to be streamlined to reach significant reduction of thermal energy consumption. The major measures that can be taken to achieve this aim are as follows:

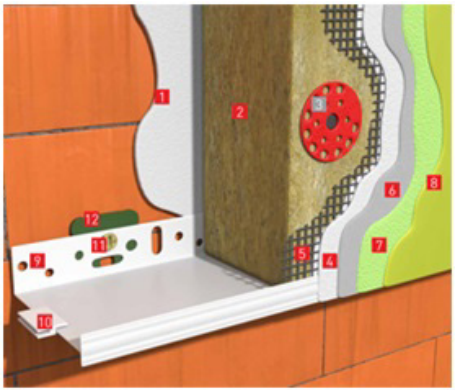
- insulation of building envelopes;
- optimization of engineering equipment operation;
- installation of any types of meters and control of resources consumption.

Heat recovery ventilation systems are not widely used since it requires considerable capital investments [9-20]. Let’s take the school № 258 in Saint-Petersburg, which was repaired and where envelopes were insulated, as an example (Fig. 4) [7]

Fig. 4. Secondary school № 258, Kolpinskiy district, Saint-Petersburg, before and after reconstruction, Kolpino, Pavlovskaya 80 A

5.4. Exterior walls insulation in case of buildings under reconstruction

The most popular insulation method is given in Fig. 5.



1 - special adhesive mixture;
2 - rock wool insulated panels;
3 - frontal expansion anchor stud;
4 - reinforcing filler;
5 – exterior glass cloth grid;
6 - water-dispersion primer;
7 - decorative mineral plaster;
8 - frontal silicone paint;
9 - ground profile;
10 - mating element;
11 - ground anchor;
12 – roughness compensator

Fig. 5. Insulation method for exterior walls

This method implies that a number of façade layers should be fixed to an exterior wall with the slabs made of rock wool serving as an insulator, and a thin finishing mortar with a reinforced pre-layer appears to be a façade layer.

5.5. Estimation of insulation effect in volume and money terms for the area of 1 m2 of an external surface of an envelope

The method for thermal technical calculations and other required reference data are assumed according to CCR 23-02-2003, D&C Specifications 23-101-2004, and D&C Specifications 131.13330.2012 «Climate change in construction industry. Revised Edition CCR (SNiP) 23-01-99*». The standard is valid from 01.01.13 as an optional document, and from July 1. 2015 as a mandatory document, Tab. 2.

Table 2. Estimated thermal and technical data.

City - Saint Petersburg Project - school	Symbol	Units	Value

Estimated temperature of outside air	text	ºC	-24
Estimated temperature of outside air during heating season	theat.seas.	ºC	-1.3
Heating season duration	zht	day	213
Estimated temperature of inside air	tint	ºC	18
Degree-day during heating	Dd	°C day	4110.9
Envelopes – exterior wall			
The coefficient assumed depending on position of exterior surface against outside air			n = 1
Rated temperature change calculated as the difference between the temperature of inside air and the temperature of an internal surface of an envelope	Δtn	ºC	4.5
Heat transfer coefficient of internal surfaces of envelopes	αint	W/m2 °C	8.7
Sanitary and hygienic indicator of thermal shield	Ro	m2 • ºC/W	1.0728
Rated reduced resistance to heat transfer in case of an envelope	Rorr	m2 • ºC/W	2.4333
Heat Transfer Coefficient of external surface in case of envelopes	αext	W/m2 °C	23
Heat transfer performance uniformity factor with due account for the impact of joints, jambs, framing rafters, flexible couplings and other thermally conductive engagements	r	-	0.6913

Reduced resistance to heat transfer of the envelope is determined according to the ratio

$$R_o^{red} = Ro \bullet r,\ m^2 \bullet ºC/W \quad (1)$$

where Ro – total resistance to heat transfer of the envelope without considering thermally conductive engagements, m2•ºC/W;

Table 3.

Number of layer	Material	Thickness of a layer, δi, m	Heat Transfer Coefficient of a layer, λi, W/m	Ri, (m2*ºC)/W
1	Exterior wall made of brick	0.64	0.81	0.79012
	1/αв			0.1149
	1/αн			0.0435
Resistance to heat transfer in case of an envelope, Ro				0.9485
Reduced resistance to heat transfer in case of an envelope, Rored				0.6557
Heat Transfer Coefficient of an envelope: K = 1.5251 W/(m2*ºC)				

Rated (required) value of the hat transfer coefficient of exterior wall:

$$K = 1/ R_o^{rr},\ W/(m2 \cdot ºC) \quad (2)$$

$$K = 1/ 2.4333 = 0.4110\ W/(m2 \cdot ºC)$$

Heat transfer coefficient of an extra insulation layer

$$\Delta ins = 0.044\ W/(m \bullet ºC)$$

Required thickness of an extra insulation layer

$\Delta ins = \Delta R \cdot \lambda / r$, m (3)

$\Delta ins = (2.4333-0.6557) \cdot 0.0440 / 0.6357=0.123$ m

Let's take

$\Delta ins = 0.1500$ m

In this case we have the following rated reduced resistance to heat transfer:

Rorr = 2.770 (m2• ºC) /W

Heat Transfer Coefficient of the envelope

K= 0.3610 (m2• ºC) /W

Difference between heat transfer coefficients of the exterior wall:

$\Delta K =1.5251-0.3610=1.1641$ W/(m• ºC) = 1.001 kcal/(h• m2• ºC)

Difference between heat losses emerged through 1 sq.m when insulating exterior walls during the heating season:

$\Delta Q = \Delta K \cdot F \cdot (tin - t\ heat\ seas) \cdot 24 \cdot zht$, kcal/m2 (4)

$\Delta Q = 98756$ kcal/m2 = 0.09876 Gcal /m2

Annual savings per 1 m2 of an exterior wall due to reduction of heating costs:

$S = \Delta Q \cdot Ph \cdot 1.18$, Rub/m2 (5)

$S = 0.09876 \cdot 1526.17 \cdot 1.18 = 177.85$ Rub/m2

Where Ph – Price rate for heat energy (without VAT)

Ph = 1526.17 Rub/ Gcal (rates for state unitary enterprise «Fuel and energy complex of Saint-Petersburg» for the first half of the year 2015).

Payback period can be calculated as follows:

Table 4.

$T = \frac{K_2}{E_1 - E_2} = \frac{\Delta K}{\Delta E}$	ΔK – costs for insulation works per 1 m2 of an exterior wall; ΔE – the difference between heat losses costs through 1 m2 of an exterior wall 1 m2 before insulation E1 and after insulation E2
$\Delta E = \Delta Q \cdot c_т$	ΔQ – difference of thermal energy losses during heating period; cт – cost of thermal energy for consumers (price rate for heating). For Saint Petersburg in 2013: cт=1702.45 rub/Gcal including VAT.
$\Delta Q = \frac{\Delta U \cdot D_d \cdot 24}{1000 \cdot 1163}$,	where ΔU – difference between heat transfer coefficients, W/(m2·°C): ΔU=U2 - U1 ; U=1/R; Dd – degree-days during the heating period. The value Dd for St. Petersburg has already been calculated, which is equal to 4110.9 °C·day / year; 24 – number of hours per day; 1000·1163– conversion coefficient from watts to Gcal.

Resistance to heat transfer of an envelope to payback period ratio can be exhibited in a chart given in Fig.4.

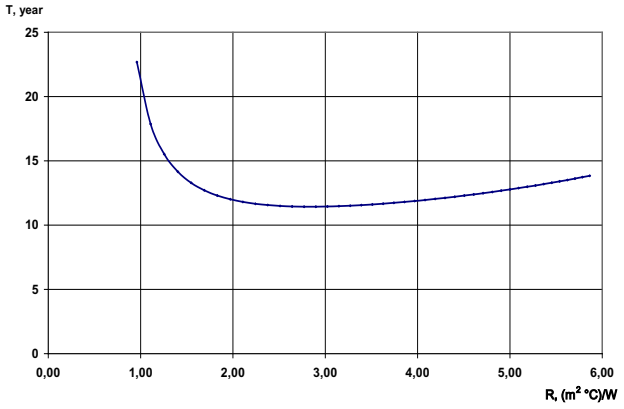


Fig. 4. Resistance to heat transfer of an envelope to payback period ratio

6. Summary

Reconstruction of school buildings is naturally interconnected with the whole educational institution network in a district and in the city as well. Common problematic issues have been revealed following from an analysis made for existing educational institutions located in the city districts. These problems may occur when it comes to reconstruction of school and pre-school buildings, and when all educational institutions are to be balanced to meet the standards of a comprehensive network as well as follows:

- to satisfy demand for a required number of vacancies according to draft design project regarding district development,
- to meet existing standards for educational institutions and to correspond to the classification list,
- to control and register lack of areas,
- to record fluctuations in occupancy rate for schools and other new public facilities.

Complex major repairs (reconstruction) assigned for educational institutions make it possible to avoid deterioration, increase service life and reliability, reduce heat energy consumption, and to ensure conditions for educational process arrangement in accordance with the standards.

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